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HYDRAULIC PUMPING AND WINDING MACHINERY SIR FRANCIS LEVEL - SWALEDALE.

P.D. Lodge

Throughout the centuries man has endeavoured to harness sources of natural power. The two main sources which immediately spring to mind are those of wind and water. In hilly terrain which has an abundant rainfall and fast running streams, water power obviously predominated, mainly by the use of water wheels which were gradually superseded by water turbines, but an interesting intermediary stage is that of water pressure engines which were of a reciprocating nature (as opposed to rotary).

Engines of this type were installed by the A.D. Mining Co. in Sir Francis Level, Swaledale in 1879. The engines which are of a great deal of interest to the industrial archaeologist are still in situ virtually as they were abandoned about 1881 and here we will describe the workings of the engines.

Plate 5, Fig. 1 shows a cross section of Sir Francis Level. It will be seen that there is a reservoir situated some distance above the mine and a [21] supply pipe 1800 ft. long leads down the hillside to a shaft which in turn leads down to the engine. The remains of the reservoir (Sun Hush Dam) can still be seen, but the 13" diameter supply pipe has disappeared except for the portion above a shaft 40 yards south of Priscilla Level. The pipe is next seen down in the engine house, immediately on the right hand side as one enters. This pipe splits into two - one the winding engine feed which is 6" diameter and the other to the pumping engine which is 8" diameter.

WINDING ENGINE.

Plate 5, Fig. 2, Plate 6 and Plates 9 & 10.

This is a horizontal, double acting, twin cylinder engine, built by Hawthorne, Davey & Co. of Leeds in 1879. The cylinders are coupled to right angled cranks on the driving shaft, which in turn drives the winding drum by a 6 to 1 reduction i.e. 6 engine revolutions equals 1 revolution of the winding drum. The final drive is a semi-shrouded spur gearing drive of approximately 1 D.P. which is, of course, different to that of more conventional winding engines which had a direct drive, i.e. connecting rods attached direct to the winding drum. Hauling engines on the other hand had a reduction similar to this particular engine.

The engine was designed to raise two tons of ore from 60 fathoms, although the actual depth from which it wound was approximately 130 foot. This is borne out by the fact that there is only 150 foot of usable rope on the drum, 5 turns on the “down” cage and 13 turns on the “up” cage. Assuming these to be symmetrical this leaves only 8 usable turns on a 6 ft. diameter drum giving 6 x 8 = 150 ft. of rope.

The cylinders which are 5½” diameter have a 16" stroke, and with the engine running at the designed speed of l9½ revolutions per minute the drum speed was 60 feet per minute.

The valve arrangements are driven by means of eccentrics having a modified Stephenson link reversing motion, and are put into equilibrium by an arrangement shown in Plate 5, Fig. 3 and Plate 10, Fig. 2.

The two mushroom inlet valves A-A are on the same spindle as two piston valves B-B each equal in diameter to the annular exhaust valves C-C. These pistons work in cylinders D-D placed beyond the engine ports and forming a continuation of the valve box. The valves are therefore in equilibrium regarding pressure, and the eccentrics have only to overcome the frictional resistance of the valves.

This, therefore, enables large valves to be used preventing loss from throttling, and reversing to be done by a link reversing motion. The directional control of the engine and the one controlling the link motion has three positions, viz. forward, neutral or idle, and reverse. The other control on the engine is a foot operated brake. The braking system is somewhat strange, only acting upon half of the winding drum; winding [22] engines brakes more often acting on the full circumference of the drum.

Presumably then, the slowing down and stopping of the engine was done by slight reversing of the engine coupled with action of the foot brake and neutralisation of valve motion. The engine at present is in neutral.

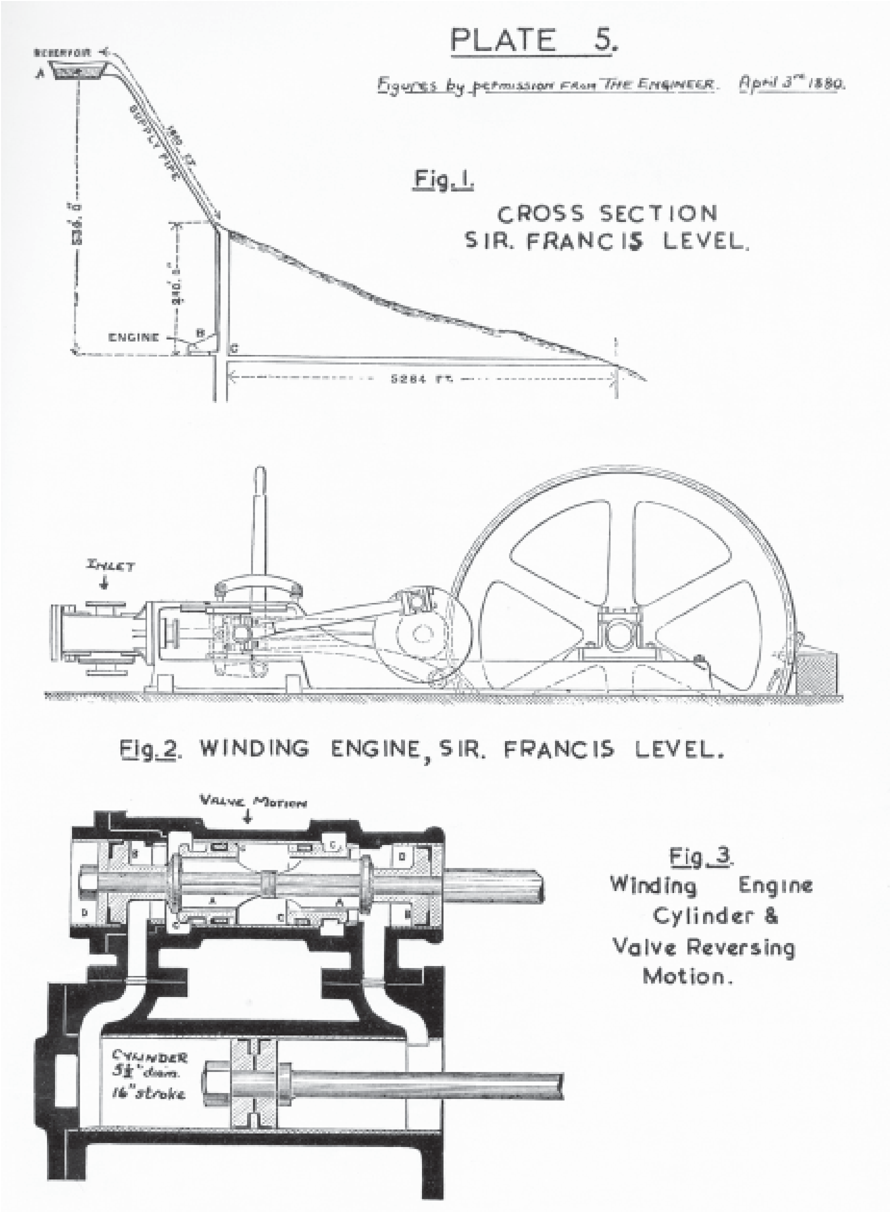
The stopping, starting and speed of the engine was controlled by means of a valve on the inlet pipe, before it splits to either cylinder. A governor would not have been considered necessary due to the more or less constant pressure of the water which was 234 lbs. per square inch.

The materials which the engines were made of was mainly cast iron – with wood on the winding drum and brass valves and liners. It is debatable whether wrought iron or mild steel would have been used.

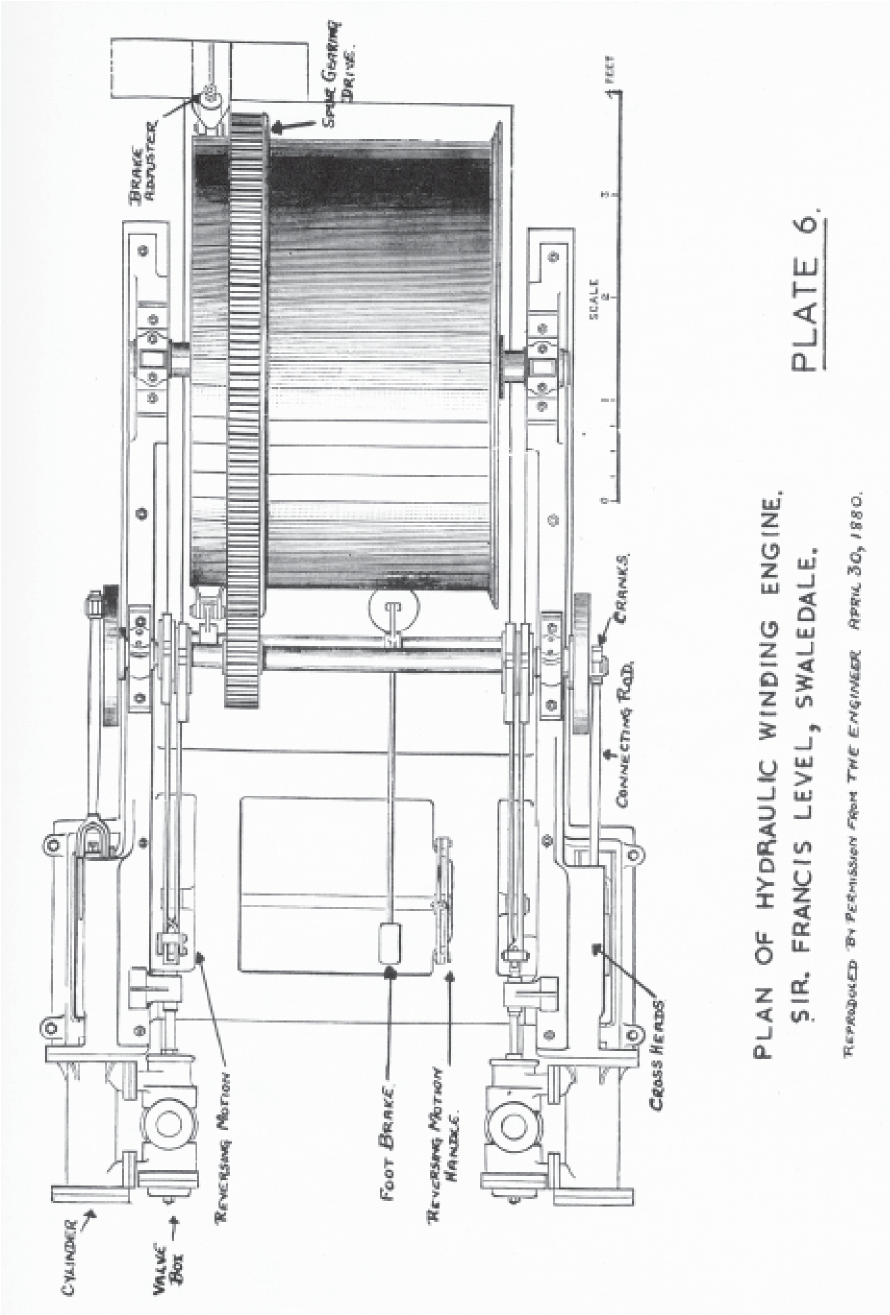
PUMPING ENGINE.
Plates 9 and 10.

This engine, like the winding engine, was built by Hawthorne, Davey & Co. Ltd. in 1879 and both engines, along with the installation, cost in the region of £4,500.

The cost of a Cornish type engine coupled to both winding and pumping would have cost approximately £3,000 and, bearing in mind the close proximity of the coalfields, it makes one wonder why the A.D. Co. chose hydraulic engines at such a cost.



The pumping engine is a vertical twin cylinder single acting on the upstroke. The power ram is 12" diameter with a 7 foot stroke. The rams are connected by a chain passing over a pulley situated on the same level as the headgear. Whilst one ram is on the up stroke, the other is on the down (exhaust) stroke.



A rod passing down through a stuffing box in the bottom of the cylinder, passed down the shaft to the pumps.

At the bottom of each cylinder is placed a valve box which controls the direction of flow to the cylinders. This box is shown in cross-section in Plate 7, Fig.1.

A change box, Plate 7, Fig. 2 and Plate 8, is attached to the left-hand cylinder and is operated by means of a slide valve, actuated by a trip lever. This lever is moved by means of adjustable trips on a rod attached to the power ram. Thus the length of the stroke could be altered by these trips. Therefore at the top and bottom of each stroke the change box is actuated. There are three small bore (1 inch diameter) pipes leading from this change box. The inlet comes in at the front. This is fed from the inlet pipe just prior to the main inlet control valve. The small valve controlling the change box inlet is now missing. Out of the left hand side of the change box comes the supply pipe which controls the left hand valve box and out of the right hand side comes the supply which controls the right hand valve box. As the slide valve moves in the change box, water is transmitted to each valve box in turn, actuating the valves and reversing the motion of the [23] cylinders.

The pumps are of the ordinary bucket type (Plate 7, Figs. 3 & 4) provided with ordinary clack pieces, door pieces and wind bores. Unfortunately the pumps were not examined, being under water. The pumps are 13" in diameter and have a 7 foot stroke.

The engine was designed to run at 6½ strokes per minute and to raise 500 gallons of water per minute from 60 fathoms, although in fact like the winding engine it only functioned from 130 feet.

Controls of the engine are on both inlet and exhaust. On the inlet, a large, two handled, screw down stop cock, and on the exhaust another circular handled stop cock. The turning of the exhaust stop cock would have been a precarious operation as one hangs out over the edge of the shaft to operate it.

Theoretical aspects of the engines.

In theory if a column of water in a pipe is stationary then the energy it possesses is given by the equation -

$$\frac{WV^2}{2g} \quad \text{ft. lbs of energy.}$$

If, however, the column of water is accelerating, then the energy it contains diminishes. On the other hand if the column is decelerating, then its energy is increased. Subsequently if the water is stopped suddenly, then the energy is expended producing a shock or blow. This is useful in a reciprocating type engine, where the valve suddenly changes the direction of the water. If the engine concerned were only to overcome friction, then the minimum power available must be equal to the friction, and if the energy varies, therefore the velocity varies, the weight being constant.

Therefore let us call the smaller and larger velocities of the water Vl and V2, the number of changes or blows per minute n, then the energy the water contains is equal to –

$$n(WV^2/2g) - n(WV^2{}_{1/}2g)$$

Where $n(WV^2{}_{1/}2g)$ is the power required to overcome friction.

As seen from Plate 1, Fig. 1 we have a total pressure head of 534 feet and from the formulae

$$P = w\,h$$

where P = Pressure of water in $lb.f/ft^2$

where: w = weight of water in $lb.f/ft^2$
h = Head of water in feet.

We can deduce the pressure of the water in the engine house.

$$P\ (lbf./ft^2) = 62.4 \times 534$$
$$= 34{,}500\ lbf/ft^2 \text{ or } 234\ lbf/ins^2$$

We now have all the basic essentials to calculate the horse power of the engines. Therefore for the winding engine from the formulae -

$$I.H.P. = \frac{P.L.A.N.}{33{,}000}$$

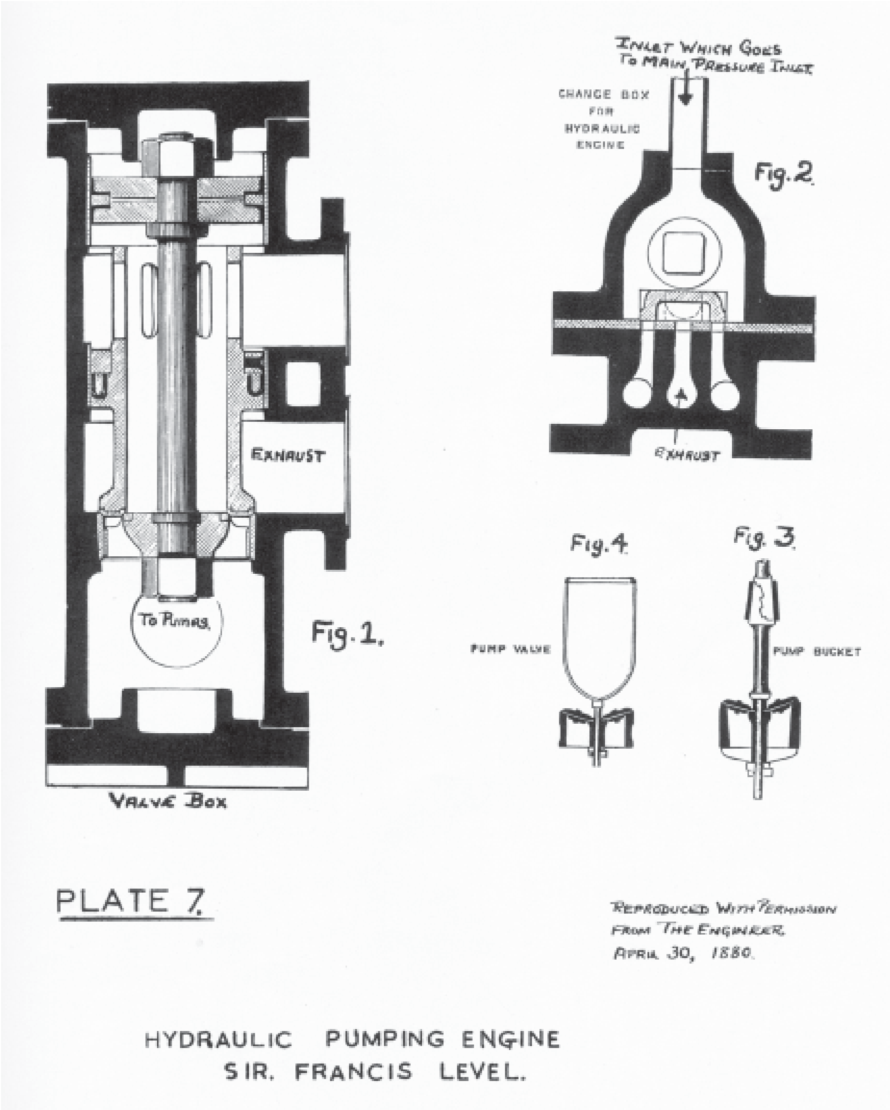
Where P = Pressure = 234 lbf/in^2
L = Length of stroke 1.3 ft. (16 in.)
A = Area of Piston 23.75 in^2
N = Number of working strokes per minute which is 78 (19.5 rev/min) on a twin double acting cylinders i.e. 4 working strokes per revolution.

$$\text{Therefore L.H.P.} = \frac{234 \times 4 \times 23.75 \times 78}{3 \times 33{,}000}$$

$$= 17.5$$

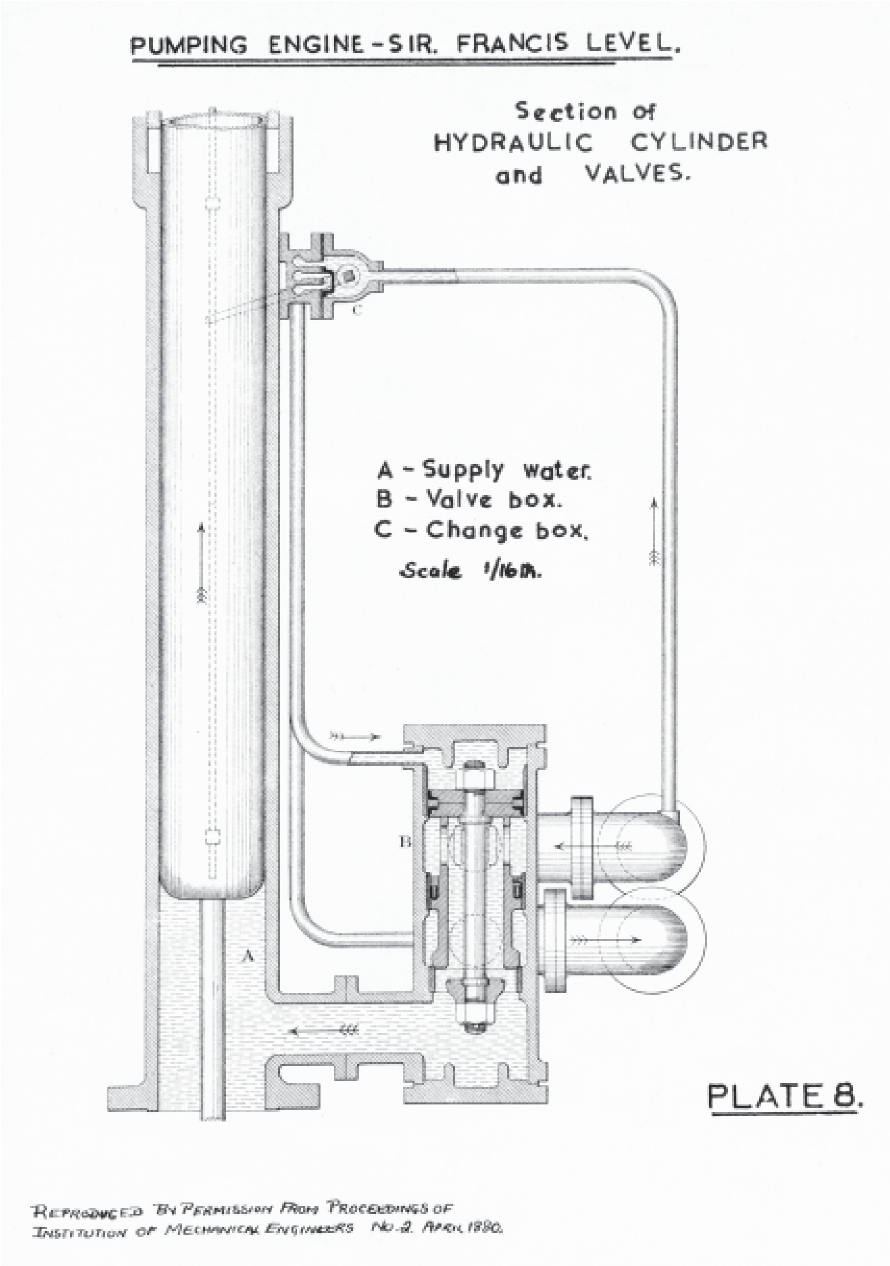
This is indicated horse power and does not therefore take the efficiency of the engine into consideration.

With the engine winding from the full depth of 60 fathoms and running at 19½ revs per minute (60ft per minute rope speed) we have a H P required to raise 2 tons of ore as:-



$$\frac{2 \times 2240 \times 60}{33,000} \quad = \quad 8.15 \text{ H P.}$$

Therefore the engine would be running with an efficiency approaching 50%, that is winding from 60 fathoms. This is of course neglecting friction. The winding engine would use somewhere in the region of 450 gallons of water every minute.


PUMPING ENGINE - SIR. FRANCIS LEVEL.
Section of
HYDRAULIC CYLINDER
and VALVES.
C
A - Supply water.
B - Valve box.
C - Change box.
Scale 1/16th.
B
A
PLATE 8.
REPRODUCED BY PERMISSION FROM PROCEEDINGS OF
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Let us now consider the pumping engine, -

The indicated horse power

$$\frac{234 \times 7 \times 113 \times 6.5}{33{,}000} = 36.5 \text{ I.H.P.}$$

At 360 ft the pressure = h w which is $\frac{360 \times 64.4}{144} = 162$ lbf/in2

and the area of the pump plunger is 133 in^2. Therefore we have a total force on the pump bucket of 21,500 lbs. The stroke is 7 ft. and we have a power requirement of

$$\frac{21{,}500 \times 7 \times 6\frac{1}{2}}{33{,}000} = 29.5 \text{ HP}$$

We therefore have an efficiency of $\frac{29.5}{36.5} \times 100 = 81\%$ efficient.

This is, of course, neglecting slip in the pump and other frictional resistances. Although to some, these calculations will appear simple, and to some appear complicated, I hope they will serve to give some indication of the power output of these unique engines.

Although these engines are still accessible, preservation seems to be only a very remote possibility due to unstable sections of the level and other factors which would have to be taken into consideration. A number of people, myself included, Seem to think that at least the winding engine could be dismantled and recovered. If this was the case a home would be found at the Bowes Museum at Barnard Castle.

ACKNOWLEDGEMENTS
I would like to thank both the Institution of Mechanical Engineers and the Editor of “The Engineer” for allowing me to reproduce material and illustrations from their proceedings. Also Mrs. M.S. Radcliffe of Draycott Hall for allowing members of the Society to visit the level.

REFERENCE

1. Davey, Henry “On Water-Pressure Engines for Mining Purposes” Proceedings of the Institution of Mechanical Engineers, April 1880.

2. “The Engineer” Vol. XLIV April 30, 1880.

3. “Sir Francis Mine” proceeding of the British Speleological Society, 1963.

[NB Hawthorne, Davey & Co. should be Hathorn, Davey & Co.]

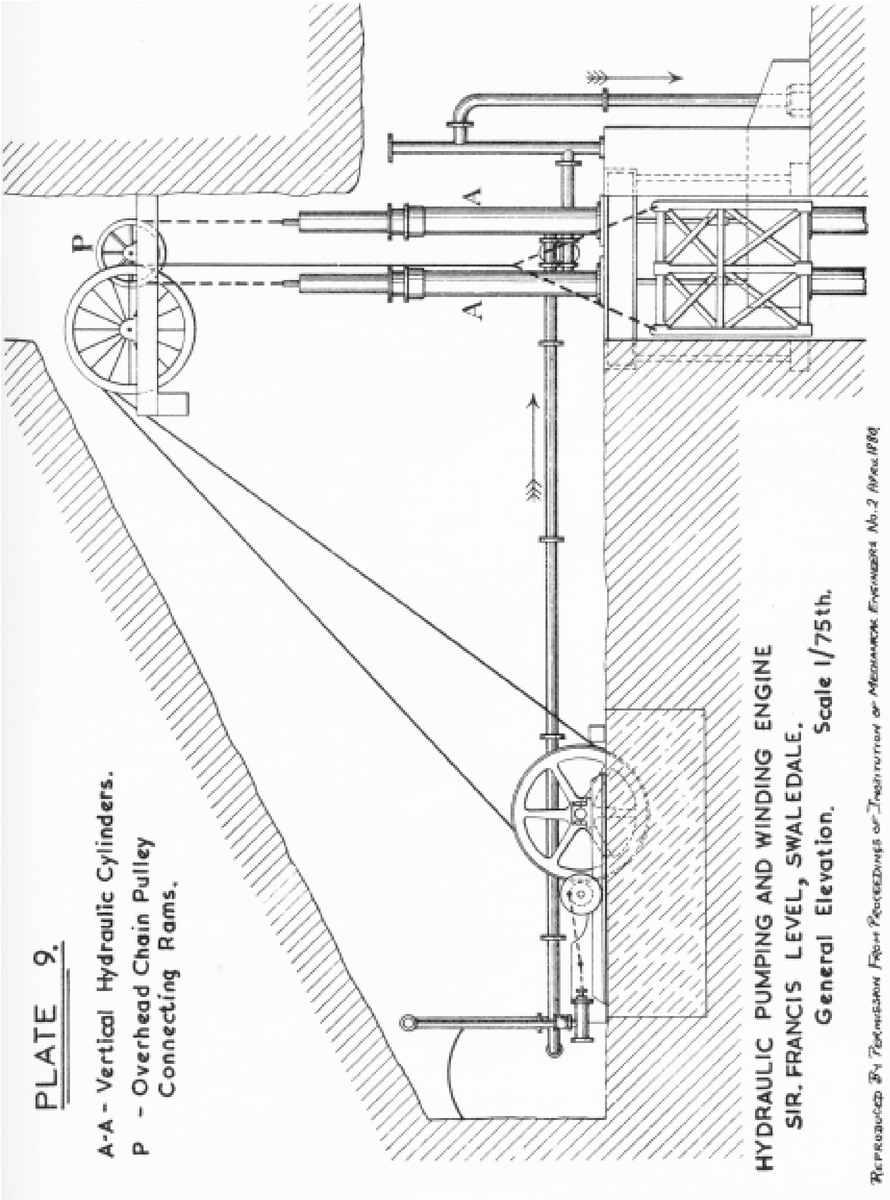
PLATE 9.
A-A - Vertical Hydraulic Cylinders.
P - Overhead Chain Pulley Connecting Rams.
P
A
A
HYDRAULIC PUMPING AND WINDING ENGINE
SIR. FRANCIS LEVEL, SWALEDALE.
General Elevation. Scale 1/75th.

SIR FRANCIS LEVEL, SWALEDALE.

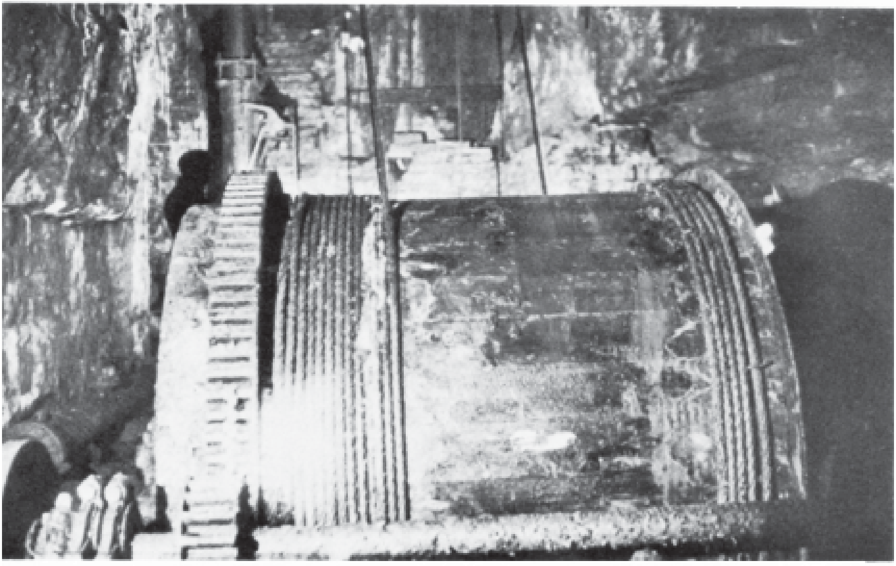

Fig.1. GENERAL VIEW DOWN ENGINE HOUSE WITH WINDING ENGINE IN FOREGROUND AND PUMPING ENGINE IN BACKGROUND

Photo. P.D.Lodge 1966

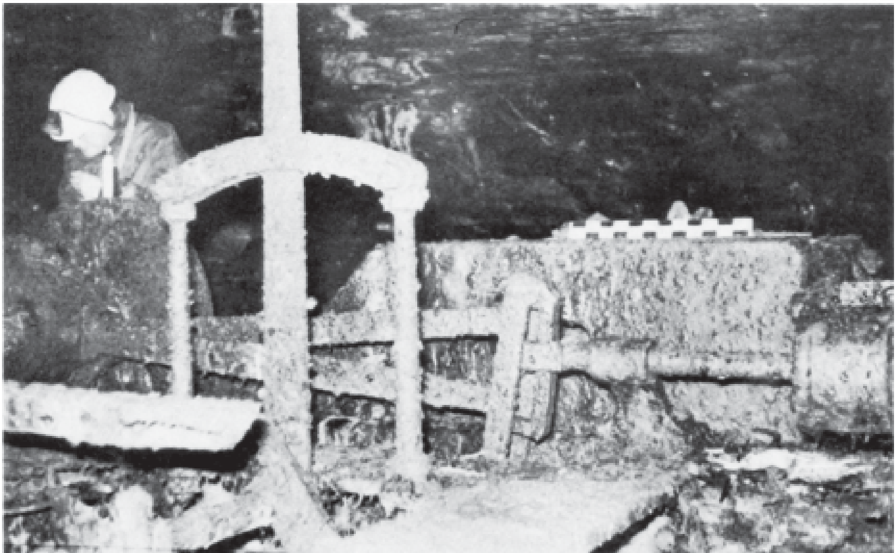

Fig.2. ECCENTRIC VALVE GEAR WITH CHANGE LEVER AND FOOTBRAKE IN IMMEDIATE FOREGROUND

PLATE 10.

Photo P.D. Lodge 1966